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**PROCEEDINGS OF THE
FIFTEENTH ARCTIC AND
MARINE OIL SPILL PROGRAM
TECHNICAL SEMINAR**

**COMPTE RENDU: 15^e COLLOQUE
TECHNIQUE DU PROGRAMME DE LUTTE
CONTRES LES DÉVERSEMENTS
D'HYDROCARBURES EN MER ET DANS
L'ARCTIQUE (AMOP)**



**JUNE 10-12, 1992
EDMONTON, ALBERTA**

**DU 10 AU 12 JUIN, 1992
EDMONTON (ALBERTA)**



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MECHANICAL RECOVERY OF OIL IN ICE

by

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ABSTRACT

Two oil spill countermeasures projects were conducted by Counterspill Research Inc. on behalf of the Canadian Petroleum Association in 1991. In the first, a literature review was undertaken of mechanical systems used for removing oil in ice. This resulted in a compilation of recovery methods, with the most promising concepts being identified for further research. In a second study, the Foxtail rope mop skimmer was evaluated in crude, diesel oil and ice, and its performance documented.

1. REVIEW OF MECHANICAL RECOVERY SYSTEMS

BACKGROUND

Since the mid-1970s, extensive work has been directed at developing methods for removing oil in ice. Although many research programs have been conducted, few commercial devices or widely accepted approaches have resulted.

In order to identify new solutions, the Canadian Petroleum Association (CPA) undertook a systematic review of mechanical techniques for recovering oil in ice. This was part of its implementation program under the Task Force on Oil Spill Preparedness in the Upstream Petroleum Industry.

Project objectives were to:

1. Review literature on the recovery of oil in ice inclusive of R&D, conceptual, evaluation and spill incident data.
2. Catalogue the compiled information according to recovery principle, and
3. Assess the potential of each concept in the context of actual cleanup.

The study considered work conducted in Canada, the USA, Norway, Sweden, the UK, and USSR. The literature were consulted extensively and the authors' experience in testing, selecting and using skimmers drawn upon as appropriate. Collected data were then organized into a catalogue format to facilitate use of the report as a reference document:

- 1.0 INTRODUCTION The study background is indicated. The most promising techniques are identified along with recommendations for future work.

2.0 MAIN ENTRIES

Devices extensively researched, prototypes, or commercially sold units are listed according to recovery principle. Entries are in alphabetical order in each of seven categories and an Index is included.

3.0 RECOVERY CONCEPTS

Ideas suggested at workshops for the recovery of oil in ice and less plausible concepts are summarized.

4.0 OIL SPILL INCIDENTS

Mechanical methods used in past spills in ice are reviewed.

5.0 REFERENCES

All references consulted during the study are listed including those sources which yielded limited data.

Forty-seven MAIN ENTRIES resulted which comprise the catalogued information requested by CPA. These were ultimately compiled from test reports, catalogues and manufacturers' brochures as follows:

Background Data

Operating Principle

Oil recovery and ice processing mechanisms.

Development Status

The stage to which the device has been taken, i.e. prototype or commercial product.

Specifications

Primary technical specifications.

Deployment

Requirements to deploy and use the system.

Performance Assessment

Test Results

Evaluation and actual use data.

Oil/Ice Processing

Existing capability to recover oil in various ice forms.

Factors Affecting Performance

The main parameters determining oil collection.

Feasibility of Use

Potential application of the device to oil and ice.

Development Potential

The projected outcome of further research on improving oil recovery in ice. High, medium and low designations are given.

References/Contacts

Sources of further technical information.

The catalogued data focuses on seven groups of skimmers organized according

1. Disc/Drum Skimmers
2. Rope Mop Skimmers
3. Sorbent Belt Skimmers
4. Submerging Plane Skimmers
5. Vacuum Skimmers
6. Weir Skimmers
7. Other Concepts/Combination Skimmers

DISCUSSION OF FINDINGS

In addition to the compendium of indexed listings presented in catalogue format as 47 Main Entries, a summary of less feasible concepts was also prepared which either hold little promise for future research or have already been considered in prototype development and testing.

Of the many spill incidents reported in conference and seminar proceedings, only a limited number specifically refer to mechanical techniques utilized for oil spill cleanup in ice. These were briefly summarized and relevant comments incorporated into the Main Entries, as appropriate.

Subsequent to their compilation, the more promising methods comprising the Main Entries were further reviewed and Low, Medium and High designations for Development Potential examined on a relative basis:

Low The device warrants no further consideration.
Medium Testing and/or modification might result in an improved system.
High Good development potential.

Results of the post-compilation analysis can be summarized as follows:

1. Skimmers studied extensively for their capability in ice include the Lockheed CleanSweep disc/drum, Marco belt and rope mop devices.
2. Of these, rope mop machines comprise the most versatile approach, largely because they can be easily deployed from vessels of opportunity in many configurations and readily positioned in oil in ice.
3. The Arcat Skimmer, which incorporates the rope mop, is well designed but could be further improved in stationary operations through the use of a single rotating brush or other system to draw oil toward the rope mop.
4. The more recently available vertical rope mop machines also warrant further development work to upgrade their performance through the use of pumps integral to the wringing mechanism, flatly configured rope mops, and guide and lead rollers which minimize inadvertent liquid losses.

5. Disc/drum skimmers now include the WP-1 Oil Retrieval System. Further research should be undertaken on this commercial device, rather than on new tank models, to determine its capability in broken ice with and without the modifications (such as paddles) investigated in past studies.
6. The Elastec Drum Skimmer should also be tested to determine optimum performance parameters in open water and broken ice. Like disc skimmers, its main advantages are ease of deployment and applicability to medium viscosity oils. Comparative tests with the Vikoma/Hoyle T-Disc Skimmer could be undertaken as well. In both cases, no developmental work on the skimmers is recommended.
7. The disc/drum concepts, however modified, are likely to continue to offer oil skimming potential in relatively low currents and calm water, with a capability to process some debris including smaller ice forms.
8. Evaluations of the three Frank Mohn Transrec skimming cassettes should be monitored. No independent development work is seen to be necessary.
9. Porous inclined planes appear to represent less potential for recovering oil in ice as compared with the other approaches.
10. Ice processors and deflectors have been developed and tested in several different formats. These have been applied to belt, weir and disc skimming systems. Generally, they can result in a more complex oil recovery system but have been shown to be capable of moving smaller ice forms to increase performance. Further research is likely to result in limited improvement to oil recovery when such systems are used.
11. The Lori brush package has potential application to relatively viscous oils. Testing of existing units should be considered to quantify its performance. Any assessment should include close examination of the operation of its mechanical components in ice.

2. FOXTAIL SKIMMER TESTS

BACKGROUND

The performance of the Foxtail VAB 8-14 Oil Skimmer was assessed in North Slope Crude Oil and diesel at the Tesoro Refinery near Kenai, Alaska Dec 2-6, 1991 under the sponsorship of the CPA and the following organizations:

- Cook Inlet Spill Response and Prevention Inc. (CISPRI)
- Alaska Clean Seas
- Environment Canada
- Marine Spill Response Corporation

The skimmer, a 900 kg device, operates through a remote power pack and pump. It incorporates eight vertically-oriented rope mops and is suspended from a crane when deployed. Fabricated by H. Henriksen Mek. Versted AS of Tonsberg, Norway, it is marketed by Nor-Marine of Oslo, Norway and Scan Pacific Enterprises, Inc. of Mukilteo, Washington, USA. See Figure 1.

Primary objectives of the test program were:

- To measure skimmer performance in oil and ice, and record associated machine settings, oil characteristics and ambient conditions.
- To assess operational functionality and suggest modifications which have the potential to improve skimming.

TEST FACILITIES

A test pit 8 x 15 x 1.2 m was excavated at the Tesoro Refinery, lined with a synthetic membrane and filled with Cook Inlet water. In addition to the crane utilized to deploy the skimmer, fish totes, Fast Tanks and pumps were used for oil distribution and collection. A 2270 L demarcated separator with bottom drain enabled quantification of recovered oil and water phases (see Figure 2).

EVALUATION METHODOLOGY

Three independent test parameters were measured: (1) oil type, (2) slick thickness and (3) ice cover. Waves were not a factor in the test pit.

Oil Type

Tests were conducted with North Slope Crude Oil and diesel. The crude oil was allowed to age during the tests, i.e. the oil used in previous tests was applied to subsequent evaluations. Test oils had the following properties:

	<u>Specific Gravity</u>	<u>Viscosity (cSt)</u>	<u>Pour Point (°F/C)</u>
Crude	0.89 to 0.97	82 - 1,340	-5/-21 to 27/-3
Diesel	0.81	3	< 60/-51

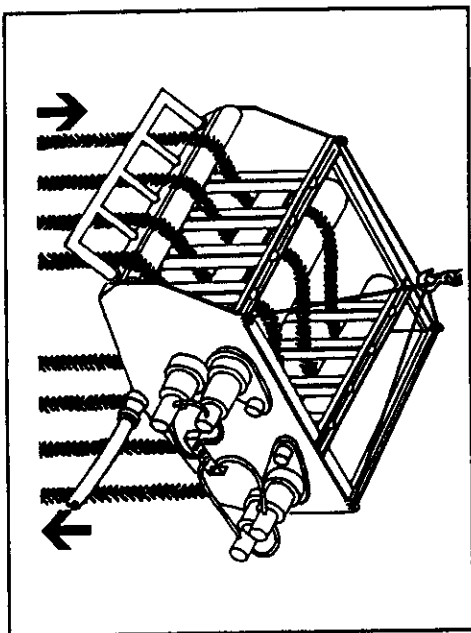
Slick Thickness

Slick thickness was set at 7-8 mm (0.3") to 10 mm (0.4") for most tests to ensure sufficient oil presentation to the mops. Thickness was estimated by dividing the volume of oil distributed for testing by the area containing it. Slick thickness could be directly measured for diesel using a barrel sampler. In the crude, water-detecting paste and a tube sampler were tried but coating was a problem.

Ice Cover

For tests in broken ice, approximately 4/10ths ice cover was utilized consisting of

FIGURE 1 FOXTAIL SKIMMER



A testing strategy was devised to isolate the effects of individual parameters on skimming in order to optimize machine performance. Skimmer adjustments thus comprised the basis for the tests:

- Mop speed (roller pressure was adjusted once)
- Length of mop contacting water
- Repositioning or sweeping of rope mop during testing

Data recorded for each test run are summarized in Table 1 and included:

- Volume of apparent oil and water phases collected
- Time for liquid recovery (usually 15 minutes)
- Observations re: mop response, mop/wringer performance, safety

Skimmer performance was based on two computed assessment parameters:

Recovery Efficiency (RE) Percent oil in the recovered oil/water mixture.

Oil Recovery Rate (ORR) Net oil collection rate (accounting for water in the recovered liquid).

Samples of the test oil and liquid recovered by the skimmer were collected and tested by laboratory analyses for viscosity, pour point and water content.

Environmental conditions were also recorded during each test:

- Air temperature (generally varied between -1°C (30°F) and 1°C (34°F))
- Water temperature at the oil/water interface [generally 32°F (0°C)]
- Wind speed (estimated at 0 - 10 knots during the tests) and direction
- Weather conditions such as precipitation and cloud cover.

Test data were summarized for each trial run and appear in the final report.

TEST PROCEDURE

Initial shutdown runs allowed personnel to familiarize themselves with operation of the complete system and to "prime" the polypropylene bands with oil. These also facilitated the selection of a range of rope mop speeds, rope mop lengths contacting the water, and collected liquid storage and transfer needs for the tests.

Testing was then conducted over a five-day period, with evaluations first run in open water using crude and then diesel oil, followed by trials with crude in broken ice. For each test, a pre-determined rope mop speed was first established followed by deployment of a known length of the rope mop in the test oil. The addition of high pressure hot water to the incoming mops was also tried.

FIGURE 2 TEST LAYOUT

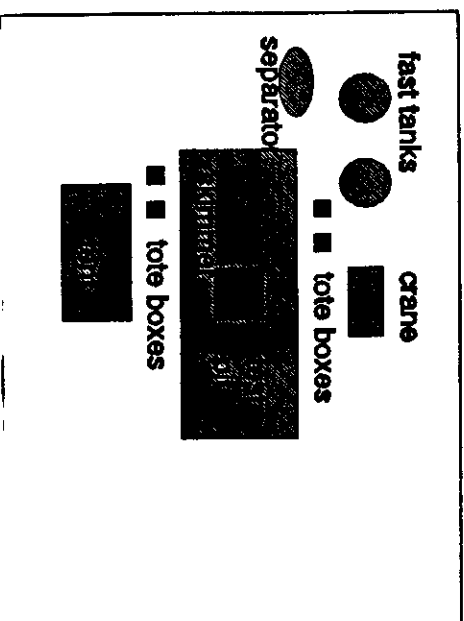


TABLE 1 TEST DATA SUMMARY

OIL PROPERTIES			ROPE MOP		Tot Liq (gal)	RECOVERY		Water (gal/%)
Pt (°C)	Visc (cSt)	Thick ("/mm)	Speed (ft/s)	Length (ft)		App Oil (gal/%)	Oil (gal/%)	
<u>T SERIES A - Open Water; Crude allowed to age during test</u>								
4	949	.2/5	1	6	400	237/59	--	163/41
3	931	.2/5	1	12	400	251/63	--	149/37
2	1,340	.3/7-8	.75	6	350	75/21	50/14	300/86
4	972	.3/7-8	.6	6	270	20/7	11/04	259/96
<u>T SERIES B - Open Water; Fresh Crude</u>								
11	299	.4/10	1	6	400	360/90	181/45	119/55
11	286	.4/10	.75	6	350	207/59	--	143/41
<u>T SERIES C - Open Water; Diesel</u>								
-51	3	.2/4	1	6	50	25/50	06/12	44/88
0/-51	3	.3/7-8	.75	6	100	50/50	38/38	62/62 diesel/crude
-51	-	.3/7-8	.75	18	100	15/15	--	85/85
-51	5	.3/7-8	.75	18	150	40/27	14/09	136/91
<u>T SERIES D - 4/10ths Ice Cover; Crude allowed to age during test</u>								
51	7	.4/10	1	6	150	80/53	45/30	105/70 stationary
17	179	.4/10	1	18	320	200/63	79/25	241/75
12	316	.4/10	.75	18	250	125/50	64/43	186/57
11	421	.4/10	.75	6	200	50/35	22/11	177/89
09	1,111	.4/10	1	18	450	170/38	57/13	393/87
08	851	.4/10	1	18	520	120/23	54/10	466/90 hot water
<u>T SERIES E - 4/10ths Ice Cover; Aged crude from previous tests</u>								
07	944	.4/10	.75	18	270	100/37	41/15	229/85
07	950	.4/10	.75	18	550	110/20	69/13	481/87 hot water
-04	1,469	.4/10	1	6	420	200/48	84/20	336/80

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DISCUSSION OF RESULTS

The Foxtail Skimmer operated optimally in thicker oil slicks of mid-viscosity (100 - 700 cSt) oil within a relatively narrow range of mop speeds: 0.2 to 0.3 m/s (0.75 to 1'/s). At higher speeds, water pickup is evident as well as excessive spray and lower efficiency of operation. Figure 3 indicates the higher total liquid recovered for crude oil versus diesel and the incremental increase in recovery rate with increased mop speed. Figure 4 shows that Recovery Efficiency (oil content) peaked with 5.5 m (18') of mop in the water travelling at 0.2 m/s (0.75 '/s).

The rope mops pick up large volumes of water if they are deployed in relatively thin slicks and contact the underlying water phase. This points to the importance of containing and concentrating slicks for most efficient use of the Foxtail Skimmer. Higher Recovery Efficiency is expected when the skimmer is deployed in slicks of several inches (>4-5 cm).

The length of rope mop in the water appears to have less effect on Oil Recovery Rate and Efficiency than does oil viscosity. The skimmer can be operated with 1.8 m (6') or 5.5 m (18') of rope mop in the water and performance is comparable for any given oil viscosity. In ice, 1.8 m of rope mop could be readily made to "walk" across the oil and ice so that the rate of forward advance matched the rope mop speed. The rope mop did not tangle in ice when 5.5 m was deployed; however, entanglement is possible in large floes with higher edges.

Although testing involved timed trials of 15 minutes each so that a common base was established, it was observed that for the mid-range of crude viscosities tested, most oil pickup occurred in the first 5 or so minutes of operation. Thereafter, recovery rate in the remaining thin slick was lower and water uptake significant.

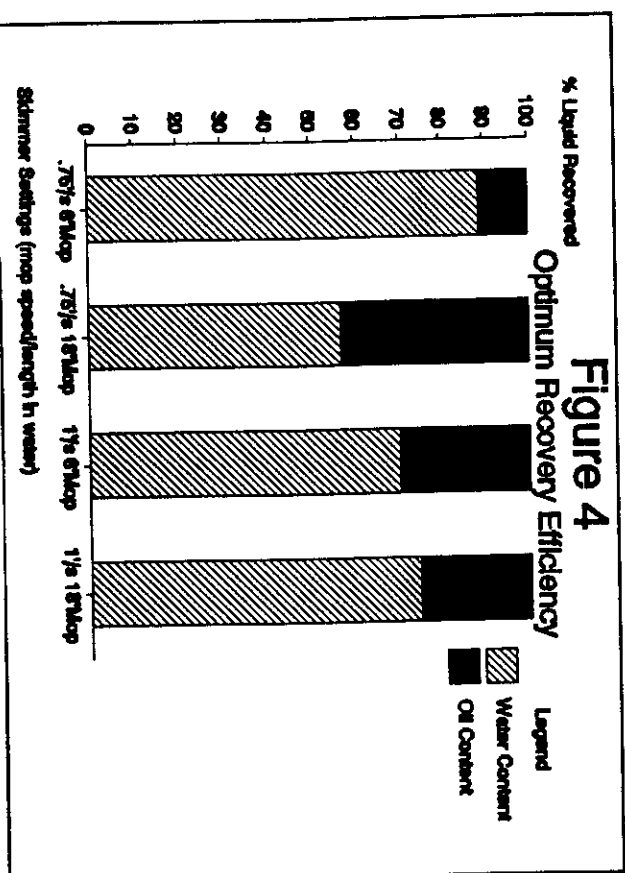
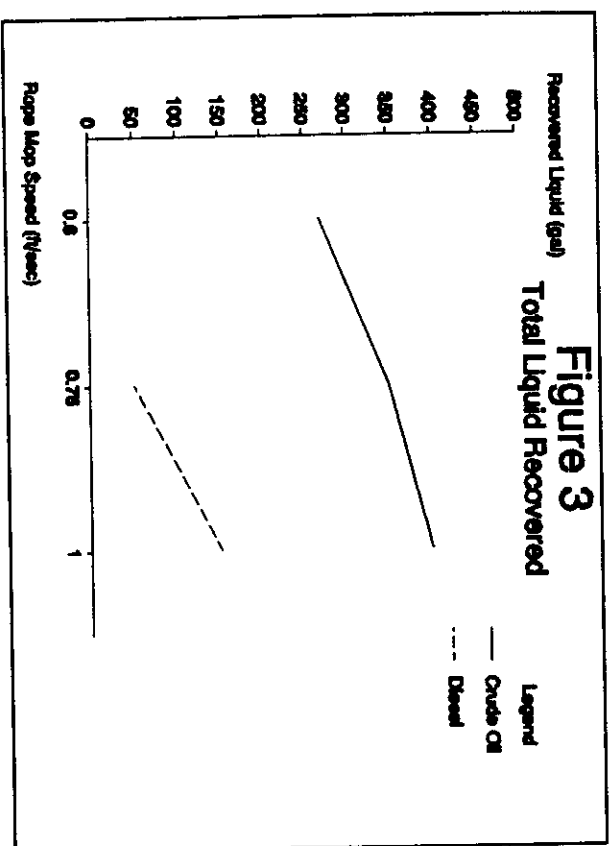
The skimmer was observed to recover oil more effectively when advanced in the same direction as the mop travel, i.e. toward the downward moving side. When moved in the opposite direction, ice pieces were pushed away from the skimmer along with oil. There is obvious merit in sweeping the mops rather than keeping them stationary as slicks are removed.

In the thinner slicks, the inside six mops play a minor role in pickup as compared with the outer two mops. (Use of the two and four band Foxtail Skimmers were discussed as possibly being more efficiently used in sweeping slicks.)

At viscosities exceeding 1,000 cSt or so, the rope mops tended to mat and recovery rate was reduced. The Foxtail did not recover diesel (0 - 5 cSt) at significant rates (see Figure 3).

Hot water at high pressure [66°C (150°F) @ 5170 kPa (750 psi)] introduced via a nozzle over each mop prior to the winger did not result in increased Oil Recovery Rate but did add substantially (over 380 L or 100 gal per 15 min) to the water recovered.

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CONCLUSIONS & RECOMMENDATIONS

1. The Foxtail Skimmer comprises an oil recovery concept that has excellent potential and affords versatility for many oil-in-ice applications.
2. The diesel/hydraulic power pack operated without mechanical problems during the entire test period and appears to be a reliable package.
3. Skimmer performance is optimal at rope mop speeds of 0.2-0.3 m/s (0.75 to 1'/sec) and in medium range viscosity oils. Mop height above the water appears to have less influence on Oil Recovery Rate. The unit is significantly less effective in diesel using the type of rope mop tested.
4. The Foxtail should be utilized in contained, concentrated slicks at least several inches thick (>4.5 cm) to operate effectively. Otherwise, the rope mops will pick up significant volumes of water upon contacting water below thin slicks. A flatter mop cross-section would improve Recovery Efficiency in such situations. Use of a 2 or 4 band Foxtail might also be considered.
5. The addition of hot water or steam nozzles is of questionable value. It did not augment skimmer performance.
6. Relocation of the pump to the sump in the puller/wringer should be considered to enable oil transfer from any vessel serving as the working platform.
7. Additional modifications should be reviewed including reconfiguration of the guide rollers and larger entry roller so that the wringing of liquid prior to entry into the wringer is reduced. A readout for mop speed and scale for the speed control lever should also be considered.
8. Pump and hydraulic connections should be specified so that these are compatible with all ancillary hardware associated with the skimmer's intended usage by North American purchasers. Metals compatibility also requires review.
9. Deployment of a Foxtail from a vessel of opportunity requires preplanning of the crane required for suspending the skimming head, the length of discharge hose, the placement of guide ropes, and liquid storage needs. Safe use of the unit in wave conditions also requires assessment.

10. Sea trials in broken ice should examine the ease of positioning the vessel and manoeuvring the mop in various ice forms so that entanglement does not occur. Associated logistical requirements should be assessed (mainly liquid storage) as well as the condition of the mops in below-freezing temperatures. Utilization of a smaller 4-band unit should be considered